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Morphometric data on the scapula and limb long bones of *Arvicola terrestris* (Linnaeus, 1758) (Rodentia, Arvicolidae)

by

Jacint VENTURA*

ABSTRACT

Data on the morphometry of the scapula and limb long bones of the northern water vole, *Arvicola terrestris*, according to sex and relative age are given. The sample was formed by 209 specimens (104 males and 105 females) captured in the Spanish Pyrenees. The whole sample was divided into six classes of relative age. The width and functional length of the scapula and limb long bones were measured in each specimen.

The results indicate a notable biometric uniformity in the scapula and limb long bones between males and females. The variables with the highest growth rate are the width and length of the scapula. The scapula and limb long bones show their maximum length increase before fourteen weeks of age. The width of the scapula shows a positive allometry against its length up to approximately the first year of age. Thereafter, this relation is isometric. The widths of the humerus and femur show a positive allometric growth against their respective lengths during adulthood. The growth rates of the length of the hind limb bones are higher than those of the forelimb.

INTRODUCTION

In the large Palaearctic distribution area of *Arvicola terrestris*, two eco-ethological types of populations are known: the digging populations from central and southwestern Europe, and the aquatic populations found in the remainder of the distribution area. These latter populations show similar habitat requirements and behaviour to the southwestern water vole, *Arvicola sapidus*, distributed in France and the Iberian Peninsula. In eastern Europe other populations with double habitat preferences (underground or aquatic according to the season) are present (KRATOCHVIL 1983). In the Iberian Peninsula there are only strictly digging populations.

Although the information published on *A. terrestris* is abundant (REICHSTEIN 1982), the bibliographic data on the morphology and morphometry of the girdles and limb skeleton are relatively scarce (BROWN & TWIGG 1969; SCHICH 1971; BOU & CASINOS 1985; BOU *et al.* 1987; LAVILLE *et al.* 1989; VENTURA *et al.* 1991). Likewise, the information on relative growth of postcranial bones is reduced to the results reported by

* Departamento de Biologia Animal (Vertebrados), Facultad de Biología, Universidad de Barcelona, Avda. Diagonal, 645, 08028-Barcelona, Spain.

BROWN & TWIGG (1969) and VENTURA *et al.* (1991) on the os coxae. The aim of this study is to give biometrical data, according to sex and relative age, on the scapula and limb long bones of an Iberian population of *A. terrestris*.

MATERIAL AND METHODS

The sample analysed was formed by 209 specimens (104 males and 105 females) captured between 1983 and 1984 in the Spanish Pyrenees (Aran Valley, Lérida). The specimens were distributed into six classes of relative age (O-V) according to the type of coat and stage of moult, morphological characteristics of the skull and sexual stage (VENTURA & GOSALBEZ 1990). The intervals of age corresponding each category are as follows (VENTURA 1988): class O: 0-3 weeks; class I: 3-6 weeks; class II: 6-10 weeks; class III: 10-14 weeks; class IV: specimens older than 14 weeks, but before the end of their first winter; class V: specimens that have wintered at least once.

The following measurements were taken (VENTURA 1990): SW: width of the scapula; SL: functional length of the scapula; HW: width of the humerus; HL: functional length of the humerus; UL: functional length of the ulna; RL: functional length of the radius; FW: width of the femur; FL: functional length of the femur; TL: functional length of the tibia. All measurements were taken with vernier calipers. The following indices were considered (VENTURA 1990): SI = (SW/SL)%; HI = (HW/HL)%; FI = (FW/FL)%; LI = [(HL+RL) / (FL+TL)] %.

The variation percentages between the means of consecutive age classes were calculated by the formula (VENTURA 1990) $VP = [(\bar{x}_{i+1} - \bar{x}_i) \cdot 100] / \bar{x}_i$, where $\bar{x}_i$ and $\bar{x}_{i+1}$ are the averages corresponding to the age classes considered. The significance of the differences between two sample means was calculated by the Student's t-test (SOKAL & ROHLF 1981). With the logarithmic values of the data, regressions were calculated by the least squares method (SOKAL & ROHLF 1981). The significance of the differences between two regression coefficients was determined by the comparison of their confidence intervals at 95%.

RESULTS

The intersexual comparisons of the averages of each parameter in all age classes reveal the existence of a high biometric uniformity between males and females. Only significant differences are present in UL in classes IV (males: $\bar{x}$=19.03, sd=0.55, n=19; females: $\bar{x}$=18.65, sd=0.52, n=22; t=2.2719, $p<0.05$) and V (males: $\bar{x}$=19.61, sd=0.51, n=17; females: $\bar{x}$=19.22, sd=0.55, n=16; t=2.1136, $p<0.05$) and in RL in class I (males: $\bar{x}$=15.17, sd=0.26, n=6; females: $\bar{x}$=14.61, sd=0.35, n=9; t=3.3369, $p<0.01$). In the indices considered, only SI in class 0 (males: $\bar{x}$=68.17, sd=1.16, n=4; females: $\bar{x}$=61.96, sd=4.66, n=4; t=2.5863, $p<0.05$) and LI in classes I (males: $\bar{x}$=83.91, sd=1.84, n=3; females: $\bar{x}$=86.38, sd=1.49, n=8; t=2.3171, $p<0.05$) and IV (males: x=82.83, sd=1.7, n=20; females: $\bar{x}$=81.21, sd=1.43, n=22; t=2.1108, $p<0.05$) show significant differences.

From these results, the data obtained in males and females were treated together (table 1). With the aim of determining the growth rate of all the variables considered, each one was correlated against the body weight, which was used as an approximate indicator of age (PELIKAN 1972; VENTURA & GOSALBEZ 1990). The confidence intervals of the regression coefficients (b) reveal that, except between HW and FL, and UL and RL, the

TABLE 1.

Values of the measurements and indices taken in the scapula and limb long bones in *Arvicola terrestris*, according to the relative age.

Variable or index	Age class	n	$\bar{x}$	sd	min.	max.
SW	0	8	6.52	0.53	5.6	7.0
	I	31	7.85	0.58	6.8	9.0
	II	42	9.30	0.52	7.9	10.7
	III	42	10.64	0.69	9.4	12.0
	IV	43	12.23	0.78	10.4	13.8
	V	41	13.13	0.68	11.6	14.7
SL	0	8	10.04	0.57	8.7	10.6
	I	31	11.58	0.73	10.2	12.9
	II	42	13.64	0.63	12.3	14.8
	III	42	15.55	0.74	14.0	15.9
	IV	43	17.21	0.79	15.2	18.8
	V	41	18.46	0.64	17.0	19.8
HW	0	9	1.43	0.11	1.2	1.6
	I	31	1.52	0.08	1.4	1.7
	II	42	1.68	0.09	1.5	1.9
	III	42	1.85	0.11	1.6	2.1
	IV	43	2.05	0.13	1.8	2.3
	V	41	2.25	0.15	2.0	2.6
HL	0	7	13.54	0.88	11.7	14.8
	I	31	15.19	0.73	13.5	16.7
	II	42	17.01	0.63	15.5	18.7
	III	42	18.51	0.67	16.8	20.3
	IV	43	19.73	0.66	18.2	21.3
	V	41	20.63	0.70	18.6	22.0
UL	0	6	14.38	0.70	13.1	15.2
	I	14	15.66	0.44	15.0	16.4
	II	26	16.80	0.69	15.7	19.3
	III	36	17.80	0.59	16.7	19.0
	IV	41	18.83	0.56	17.7	20.0
	V	33	19.42	0.56	18.3	20.4
RL	0	6	13.62	0.76	12.3	14.7
	I	15	14.81	0.40	14.0	15.4
	II	37	16.03	0.48	15.0	16.7
	III	38	17.12	0.50	16.0	18.4
	IV	42	18.00	0.54	16.8	19.0
	V	40	18.63	0.51	17.6	19.8
FW	0	9	1.81	0.18	1.5	2.0
	I	31	2.07	0.15	1.8	2.4
	II	42	2.35	0.13	2.1	2.6
	III	42	2.58	0.76	2.0	3.0
	IV	43	2.89	0.20	2.5	3.4
	V	41	3.07	0.21	2.7	3.4
FL	0	7	14.07	0.81	12.3	15.0
	I	29	15.74	0.82	14.3	17.2
	II	42	18.02	0.74	16.8	20.0

TABLE 1. (continuation)

Variable or index	Age class	n	$\overline{x}$	sd	min.	max.
	III	42	20.03	0.76	18.0	21.8
	IV	43	21.69	0.75	20.0	23.0
	V	41	23.04	0.75	21.7	24.9
TL	0	6	17.70	0.32	17.4	18.3
	I	23	19.17	0.94	17.7	21.2
	II	34	21.62	0.78	20.2	23.4
	III	37	23.12	0.87	20.1	24.4
	IV	43	24.49	0.78	21.9	25.7
	V	40	25.83	0.83	24.4	27.7
SI	0	8	65.07	4.61	53.37	70.10
	I	31	67.82	2.68	61.95	73.73
	II	42	68.17	1.79	58.09	72.66
	III	41	68.40	2.39	63.51	72.73
	IV	42	70.94	2.67	64.07	76.40
	V	41	71.12	2.98	64.40	79.00
HI	0	7	10.65	0.66	9.70	11.85
	I	31	10.03	0.51	9.26	11.27
	II	42	9.89	0.55	8.52	11.61
	III	42	9.98	0.48	9.04	11.11
	IV	43	10.41	0.62	9.04	11.70
	V	41	10.92	0.68	9.52	12.63
FI	0	6	13.17	0.88	12.19	14.28
	I	29	13.16	0.64	11.73	14.46
	II	42	13.08	0.72	11.50	14.77
	III	42	12.89	0.79	9.52	14.35
	IV	43	13.31	0.89	11.36	15.53
	V	41	13.32	0.85	11.54	14.80
LI	0	4	86.97	1.31	85.26	88.59
	I	11	85.70	1.93	81.32	87.88
	II	30	83.56	1.23	80.67	85.71
	III	33	82.37	1.38	79.38	86.32
	IV	42	81.69	1.65	77.20	88.10
	V	39	80.33	1.26	77.40	82.63

slopes of the remaining regression are significantly different (table 2). SW is the variable that shows the highest slope against body weight. The length of the proximal bones of each limb shows higher regression coefficients than that of the distal ones. Moreover, the femur shows a higher growth rate than the humerus, and the tibia grows faster than the ulna and radius (table 2).

The lengths of the scapula and limb long bones generally show a progressive diminution of the variation percentages of the means between consecutive age classes (table 3), higher values appearing in 0-I (HL, UL and RL) or in I-II (SL, FL and TL) intervals. From this last interval, the variation rates diminish until class V. The variation percentages of the widths of the scapula, humerus and femur decrease from the lowers (O-

TABLE 2.

Values of the regression equations (log y = b log x + log a) for the correlations between body weight (x) and all the measurements considered (y).

y	log a	b	Confidence intervals of b (95%) minor	Confidence intervals of b (95%) major	r	n
SW	–0.0513	0.5388	0.5153	0.5623	0.9528	207
SL	0.2233	0.4810	0.4646	0.4974	0.9702	207
HW	–0.4952	0.3845	0.3622	0.4068	0.9207	208
HL	0.6138	0.3241	0.3119	0.3363	0.9643	206
UL	0.7915	0.2290	0.2146	0.2434	0.9288	156
RL	0.7544	0.2378	0.2248	0.2508	0.9375	178
FW	–0.4188	0.4168	0.3949	0.4387	0.9337	208
FL	0.5176	0.3894	0.3757	0.4031	0.9689	204
TL	0.7700	0.2956	0.2816	0.3096	0.9509	183

TABLE 3.

Variation percentages between the means of consecutive age classes in the measurements and indices considered.

Variable or index	0-I	I-II	II-III	III-IV	IV-V
SW	20.40	18.47	14.41	14.94	7.36
SL	15.34	17.79	12.28	10.67	7.26
HW	6.30	10.53	10.11	10.81	9.76
HL	12.19	11.98	8.82	6.59	4.56
UL	8.90	7.28	5.95	5.79	3.13
RL	8.74	8.23	6.80	5.14	3.50
FW	14.36	13.53	9.79	12.01	6.23
FL	11.87	14.48	11.15	8.29	6.22
TL	8.30	12.78	6.94	5.93	5.47
SI	4.22	0.52	0.34	3.71	0.25
HI	–5.82	–1.40	0.91	4.31	4.90
FI	–0.08	–0.61	–1.45	3.26	0.07
LI	–1.46	–2.50	–1.42	–0.82	–1.66

I in SW and FW, and I-II in HW) to the II-III intervals, relatively high values appearing in the next (table 3).

The indices considered show particular variation patterns with relative age. SI progressively increases its averages from classes O to V (table 1), specially in the III-IV interval (table 3). The differences between the mean values obtained in the extreme categories (O, V) as well as in classes III and V are significant (O-V: $t=4.7801$, $p<0.001$; III-V: $t=4.5689$, $p<0.001$).

The HI averages diminish significantly between classes 0 and II (t=3.2935, p<0.01). In the interval between classes II and V the mean of this index increases significantly (t=7.5767, p<0.001) (table 1). This increase can be verified when the relatively high percentages of variation (4-5%) in the last two age intervals are taken into account (table 3).

The FI index follows a similar variation pattern to that of HI, although FI shows a smaller range (table 1). Thus, the average values diminish, albeit not significantly, between classes 0 and III, and from this latter one the means of FI increase significantly until class V (t=2.3859, p<0.05). Nevertheless, this increase is relatively less marked than that observed in HI in the II-V interval.

The LI averages decrease from classes 0 to V with relatively constant rate (tables 1 and 3). The differences between the means of these age classes are clearly significant (t=10.0079, p<0.001).

DISCUSSION

Although significant differences between males and females are observed in some parameters, due to the higher biometrical similarity in most of the intersexual comparisons performed, it can be stated that there is no sexual dimorphometry in the scapula and limb long bones in the population analysed.

Taking into account the values of the regression coefficients and their confidence intervals, the width of the scapula is the parameter that shows highest growth rate. The long bones of the hind limb grow faster than those of the forelimb. Likewise, in each limb, the proximal bones show the highest growth rate.

The variation percentages between the averages of consecutive age classes reveal that the scapula and the limb long bones show their maximum length increase before fourteen weeks of age, approximately. The widths of the scapula, humerus and femur show a relatively high increase starting from fourteen weeks of age. In the correlation against the body weight, these parameters show significantly higher growth rate than the corresponding lengths.

The means of SI in adult specimens (classes IV and V) are about 71%. This value is lower than that obtained in *A. sapidus* (75.1-76.1%; VENTURA 1990). These differences can be attributed to functional factors determined by the different eco-ethological characteristics of the two species. Thus, the relatively longer scapula shown by underground rodent species (SCHICH 1971; LAVILLE *et al.* 1989) may be the factor that determines the interspecific differences detected.

The variation pattern of SI with relative age in *A. terrestris* is, in general terms, similar to that obtained in *A. sapidus* (VENTURA 1990). In both species, the width of the scapula shows a positive allometry against length up to, approximately, the first year of age. Thereafter, this relation is isometric.

The averages of HI in adult specimens vary between 10.4-11%. These values are notably higher than those detected in *A. sapidus* (8.3-8.6%; VENTURA 1990).This interspecific relation coincides with the results obtained by CABRERA-MILLET (1980). Taking into account the data reported by BOU *et al.* (1987)., the differences between these two species may be due to the relatively higher width that show the proximal bones of the fore limb in underground rodent species. Likewise, digging species tend to have shorter limb bones (BOU *et al.* 1987).

During the first ten weeks of life, approximately, the length of the humerus shows a positive allometry against width. Thereafter, the allometric growth is favourable to the width. This variation pattern is similar to that reported in *A. sapidus* (VENTURA 1990), but the increase that occurs during adulthood is higher in *A. terrestris.*

The average of FI in adult specimens is about 13.3%. This percentage is clearly higher than that observed in *A. sapidus* (11.3-11.7%; VENTURA 1990). These results coincide with the data of BOU *et al.* (1987), which indicate that underground rodent species tend to have relatively shorter limb bones.

During the fourteen first weeks of life, the length and width of the femur vary isometrically, existing a relative light increase of the length. From this age on, the averages of FI increase due to the positive allometry favourable to the width during adulthood. The variation pattern of FI with relative age is similar to that reported in *A. sapidus*, but the range of variation is higher in this species (VENTURA 1990).

The mean values of LI in adult specimens vary between 80.3-81.7%. These percentages are notably higher than those observed in *A. sapidus* (74.1-74.9%; VENTURA 1990). This interspecific relation coincides with the results reported by CABRERA-MILLET (1980). According to SCHICH (1971) and CABRERA-MILLET (1980), the aquatic rodents show relative longer hind limbs. This fact determines the lower averages of LI observed in *A. sapidus* in relation to *A. terrestris.*

The regression coefficients obtained in the correlations of each limb long bone length against the body weigth indicate that the hind limb shows a siginificant higher growth rate than the forelimb. The variation pattern of LI until fourteen weeks of age, approximately, is similar to that observed in *A. sapidus* (VENTURA 1990). During adulthood LI averages diminish lighter in both species.

The results obtained indicate some differences in the growth patterns of the scapula and limb long bones between the two Palaearctic species of *Arvicola.* The precise determination of these patterns and their adaptative and phylogenetic significance will be stated when studies on this matter on the aquatic populations of *A. terrestris* are undertaken.

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